INTERNATIONAL JOURNAL OF SCIENTIFIC PROGRESS AND RESEARCH (IJSPR) ISSN: 2349-4689
Issue 179, Volume 79, Number 01, January 2021

A Review on Harmonic Elimination and Load balancing using Distributed Compensator

Laxman Prasad Patel, Arvind Jain

Abstract:* In present day scenario, it is most essential to consider the maximum asset performance of the power distribution systems to reach the major goals to meet customer demands. To reach the goals, the planning optimization becomes crucial, aiming at the right level of reliability, maintaining the system at a low total cost while keeping good power quality. There are some problems encountered which are hindering the effective and efficient performance of the distribution systems to maintain power quality. These problems are higher power losses, poor voltage profile near to the end customers, harmonics in load currents, sags and swells in source voltage etc. All these problems may arise due to the presence of nonlinear loads, unpredictable loads, pulse loads, sensor and other energy loads, propulsion loads and DG connections etc. Hence, in order to improve the power quality of power distribution systems, it is required to set up some power quality mitigating devices, for example, distribution static synchronous compensator (DSTATCOM), dynamic voltage restorer (DVR), and unified power quality conditioner (UPQC) etc. The goal of this review work is to devise a planning of optimal allocation of DSTATCOM in distribution systems using optimization techniques so as to provide reactive power compensation and improve the power quality.

***Keywords:* DSTATCOM, DVR, UPQC, Distribution Systems, Power Quality.**

I. INTRODUCTION

In electricity system, frequency fluctuation trouble is a worldwide problem and dealt globally. Power quality is a concern that becomes gradually vital to electricity customers in all respective degree of usage. The growing range of power electronics based equipment has dangerously impacted the exceptional of electric power supply. With each linear load in system, harmonics are produced which reduces power quality. This indicate the harmonic in strength supply system gives a severe power quality issues that consequences in greater power losses in the distribution system and liable for operation disasters of electronic equipment. As in three phases the 5th, 7th and 11th order harmonics are greater dominating so the current wave is not pure sin wave. To introduce dynamic and adaptable result of such power quality disturbances, efforts are continue by means of the affect of power electronic devices, FACTS, filters and different type of control technique to compensate the power quality problems. The performance of DSTATCOM depends on the selection of interfacing of ac inductor, DC bus capacitor and IGBT. Various researches presenting a complete evaluate on compensating device for improvement of power quality from the system. By using active power filters, synchronous condensers, passive filters, compensating devices such as shunt compensating device (DSTATCOM) series compensating device (DVR) and hybrid of shunt and series compensating device (UPQC) [1, 2].

1.1 Facts Controller Devices

Power systems voltage and current waveforms are deteriorates by highly use of power converters and nonlinear loads. Harmonics are generated because of high frequency of switching of power electronics converters. The presence of harmonics in voltage and current waveforms increases the power loss. The unbalanced load current with large reactive components leads results in voltage fluctuations and unbalance due to the source (system) impedances. Because of unbalanced current the harmonic components increases and reduction in power factor of distribution network. A shunt compensator also helps to reduce voltage fluctuation sat the point of common coupling (PCC). If the source voltages are unbalanced and varying, it is also possible for a shunt compensator to achieve this [1].

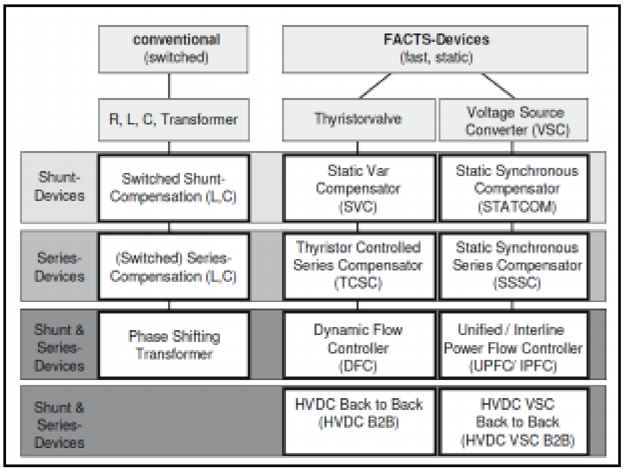

Fig. 1.1 Overview of FACTS Devices

The commonly FACTS controller devices used for improving the power quality are as follows:

- Static VAR Compensators (SVC)
- Thyristor Controlled Series Capacitors (TCSC)
- Static Compensators (STATCOM)
- Static Series Synchronous Compensators (SSSC)

- Unified Power Flow Controllers (UPFC)

Among of the various distribution FACTS controllers, Distribution Static Compensator DSTATCOM is an important shunt compensator which has the capability to solve power quality problems faced by distribution systems.

2. DSTATCOM

A DSTATCOM is a device which is used in AC distribution system where harmonic current, reactive current compensation and load balancing are necessary the building block of a DSTATCOM is voltage source converter (VSC) consisting of self commutating semiconductor valves and a capacitor on a dc bus the device is shunt connected to the power distribution network through a coupling inductance. In general, the DSTATCOM can provide power factor correction, harmonic compensation and load balancing. The major advantages of DSTATCOM compared with a conventional static VAR compensator (SVC) include the ability to generate the rated current at virtually any network voltage. better dynamic response and the use of relatively small capacitor on the dc bus the size of the capacitor does not play an important role in steady state reactive power generation which results in a significant reduction of the overall compensator size and cost[2].

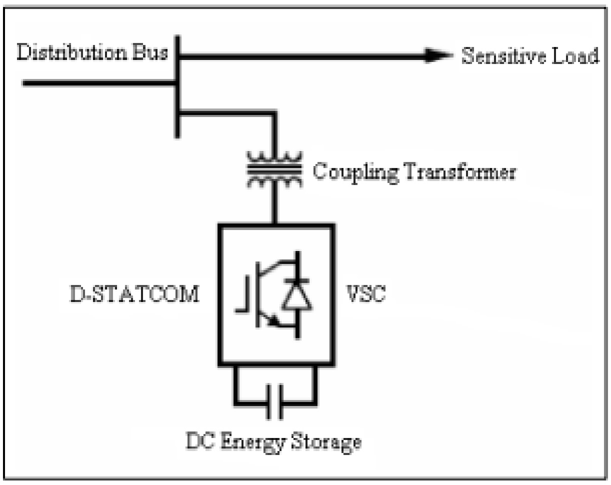

Fig. 2.1 Basic Configuration of DSTATCOM

3. REVIEW OF LITERATURE

1. N. G. Hingorani et.al., explains how it is now becoming acquainted with the idea of custom control. The concept defines the value-added electricity that will be provided to its consumers in the future by electrical utilities and other service providers.
2. K. E. Stahlkopf, et.al., et.al., et. It defines the operation and the components of the versatile AC transmission system (FACTS). Reliable, high-speed power electronic controls are used by FACTS, developed to solve the shortcomings of existing mechanically operated AC power transmission systems.
3. Gyugyi, et al., works with Thyristor Controlled (TCR) and GTO Controlled Series Capacitor (GCSC) modeling of controlled series transmission line compensation equipment. The paper also discusses experimental observations of a single-phase system-connected TCR and GCSC.
4. The application of static reactive compensators (SVCs) to power transmission systems applies to L. Gyugyi et al. Descriptions of static VAR compensators are provided in the document, with technological and economic comparisons of the various compensators.
5. N. G. Hingorani et.al., Details Perception, Scalable AC Transmission Systems Principles and Technologies, Piscataway, NJ: IEEE Press (2000).
6. K. R. Padiyar, et.al., discusses the emerging Modular AC Transmission System (FACTS) technology that allows power systems to be designed and run at minimal cost, without losing protection. This is focused on new electronic high-power systems that have rapid controllability under evolving device conditions to ensure 'flexible' operation. Through explaining the operational principles, computer simulations, control architecture and problems that impact the implementations, this book provides a detailed treatment of the subject.
7. 7. Y. L. Tan, et.al., et.al., This tackles the question of A new approach for the efficacy study of an SVC and a STATCOM of the same kVAr ranking for first-swing method to ensure is presented and a numerical illustration illustrates the principle. The study reveals that the STATCOM for first-swing stability change is superior to the SVC.
8. P. Gonzalez et al. discuss the PWM-based STATCOM control system. Firstly, it is the STATCOM's discrete model that takes care of the controller's discrete execution. The second argument is the thorough control algorithm. It guarantees a decoupled control between the power transmitter and the electricity-energy grid with actual and reactive power. The voltage of the DC condenser needs to be tested during transient reactive power exchange. Finally, the voltage regulation of the condenser is comprehensive.
9. B. Singh, et.al., Analyzing the wind turbine with a direct-driven PMSG, this paper proposes a low voltage ride through scheme of PMSG wind power systems based on feedback linearization. The DC-Link voltage is controlled by the generator-side converter rather than the grid-side converter. Considering the nonlinear relationship between the DC-Link voltage and the

generator rotor speed, the controller of DC-Link voltage uses a feedback linearization technology.

10. G. F. Reed et.al., introduces the concept of DSTATCOM Fuzzy Logic Controllers (FLC) to increase the power efficiency of a distribution system. The PI controlled DSTATCOM could provide optimal performance under different operation conditions because the power process is completely nonlinear and due to various disruptions. In order for DSTATCOM to have sufficient dynamic voltage control and contribute to the stability and reliability of the power distribution network, more powerful controllers such as those based on the fuzzy logic approach are needed.
11. A. Ghosh et.al., Using a delivery static compensator to address load compensation (DSTATCOM). The DSTATCOM is believed to be connected to a load which is distant from the supply. A new switching control scheme is introduced in this paper and shows its suitability for this problem. It also suggests a scheme in which it is possible to compute the essential sequence components of the three-phase signal with its samples.
12. A. Ghosh et.al., presents a modern method for developing active filter and/or static compensator reference currents. Instantaneous symmetrical components the authors use to achieve an algorithm to calculate three-phase reference currents, which yield desired effects when pumped into the power supply. They also suggest an appropriate compensatory framework to monitor reference currents in a band control system with hysteresis..
13. M. K. Mishra, et.al., Created a novel STATCOM topology capable in 3 stage 4-wire distribution systems to provide AC and DC loads. This is the approach used by the authors to derive compensator reference courante from the immediate symmetric elements, which are monitored in the hysteresis band existing control scheme.
14. S. Kincic et.al., has a DSTATCOM (Static Compensator distribution), used to stabilize loads and decrease harmonics.
15. Ambarnath Banerji et.al., Describes the converter's separate prediction models. The ways in which the converter mitigates power quality problems are also discussed. On the MATLAB platform, demonstrations of controller design are carried out to assess the efficacy of each power quality reduction control system.

16. S. Bhattacharya, et.al., A D STATCOM (Distribution Static Compensator) research used mostly for load balance and harmonic mitigation is presented. Using a D-STATCOM, the basic principle of voltage sag mitigation is to dynamically insert into the grid line a current of the appropriate amplitude, phase and frequency.

17. H. Akagi et.al., It addresses and analyzes a new current management approach for active power filters with multiple PWM inverters. Each PWM voltage inverter works with a different modulation index and generates some current, frequency distortions of the load. The suggested current control strategy.

18. M. Kazerani, et.al., a new approach for the correction of the input power factor is introduced using the active closed-loop wave formation technology. The new function of the system is that almost sinusoidal input currents are observed at frequencies of continuous switching. In addition, the mechanism has instantaneous power, resulting in very rapid reaction and improved transfer efficiency.

19. F. Z. Peng, H et.al., A DC condenser constant voltage circuit is being recommended. The debates are based on the immediate reactive power principle, which concentrate on temporary states. A passive LC filter is intended for eliminating current and voltage ripples from the AC side of the PWM converters.

4. POWER QUALITY PROBLEMS

Electricity consumers face power quality problem at all stages of usage. Actually, Power quality defines the assets of power supply distributed to the users in normal operating conditions. New electronic equipments and devices are more prone to power quality problems. Reduced PQ has become a major problem for both power suppliers and customers. Poor PQ means there is enough variation in the power supply to affect equipments and may lead to their mis-operation or failure.

From above discussion it can be said that Power Quality problem means power supply that causes inconvenience or production loss; deviation in voltage, current, frequency that results in failure or mal-operation of consumer equipment; unsatisfactory consumer service.

4.2.1 Transients

Transients are rapid deviations of the voltage values for durations from a several microseconds to few milliseconds [1]. These variations may reach thousands of volts, even in low voltage. Transients are of two types which are given below:

4.2.1.1 Impulsive Transients

An impulsive transient is a short unidirectional change in voltage, current, or both on a power line as shown in Figure 3.1. The main causes of impulsive transients are lightning, switching of inductive loads and disconnection of heavy loads [4]. The impulsive transient affects electronic components, insulation materials, and produce data processing errors and electromagnetic interference.

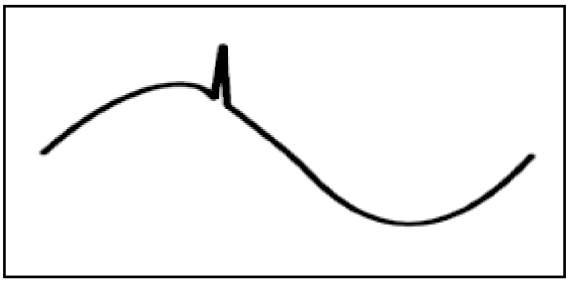

Fig. 3.1 Impulsive Transients

4.2.1.2 Oscillatory Transients

An oscillatory transient is a small bidirectional change in voltage, current, or both on a power line. Reasons behind these transients are power factor correction capacitors, switching of inductive loads and transformer ferro-resonance. The effects of oscillatory transients are failure of insulation materials, overheating of all cables, equipment and electromagnetic interference.

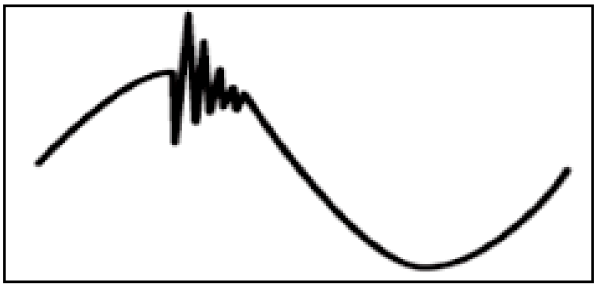

Fig. 3.2 Oscillatory Transients

4.2.1.3 Voltage Sag

Voltage sag [1] is defined as a drop in the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0. 5 cycle to 1 minute. It is clear from Figure-2.1 that voltage sag reduces the magnitude of voltage.

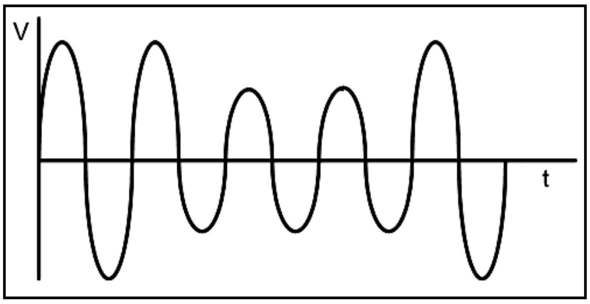

Fig. 3.3 Voltage Sag

Connection of heavy loads, start-up of large motors and faults in consumer’s installation are the main reasons for voltage sag. Starting of large induction motors can result in voltage dip as the motor draws a current up to 10 times the full load current during the starting. The Consequences of voltage sag are disconnection and loss of efficiency in electric rotating machines, tripping of electro-magnetic relays and malfunction of information technology equipment namely micro-processor based control systems.

4.2.2 Voltage Swell

Voltage swell is defined as momentary increase of the voltage at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds. Figure 3.4 shows the rise in voltage magnitude due to voltage swell [28]. Voltage swell is caused due to line faults, badly dimensioned power sources and incorrect tap settings in tap changers in substations. A SLG (single line to ground) fault can result in a voltage swell in the healthy phases. Swell can also result from energizing a large capacitor bank. The consequences of voltage swell are flickering of lighting and screens, data loss and stoppage or damage of sensitive equipment.

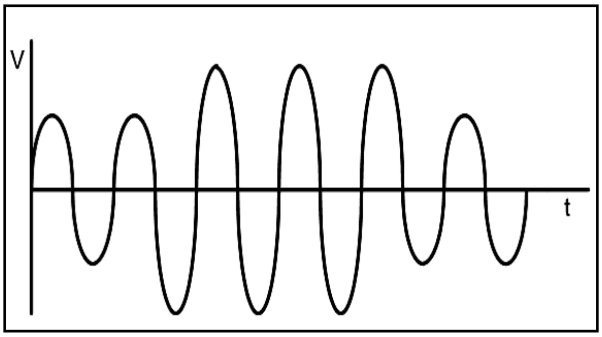

Fig. 3.4: Voltage Swell

4.2.4 Interruption

A very short but complete loss of supply is called an interruption. An interruption occur when the supply voltage reduces less than 10% from its original value up to a period of time not exceeding one minute. The number of interruptions of the supply also increases voltage sag which needs a proper mitigation [27].

4.2.4.1 Very Short Interruption

Very short interruption [2] is defined as complete interruption of electrical supply for duration from few milliseconds to one or two seconds.

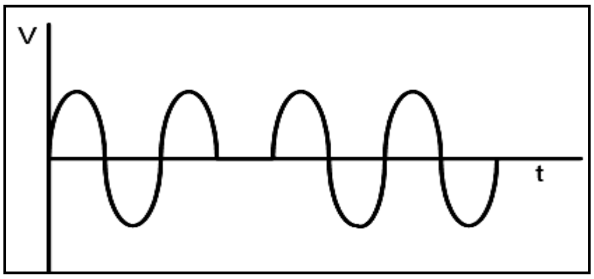

Fig. 3.5 Very Short Interruptions

It is caused due to insulation failure, lightning, system faults, equipment failures and insulator flashover. The consequences of very short interruption are loss of information and malfunction of data processing equipment, tripping of protection devices and stoppage of sensitive equipment.

4.2.4.2 Long Interruptions

Long interruptions are defined as loss of utility power lasting more than 2 minutes due to major local area or regional electrical incidents [2]. These are caused by equipment failure in the power system network, storms and objects striking lines or poles, power system faults and control malfunctioning causes long interruptions. Long interruptions result in stoppage of all equipment.

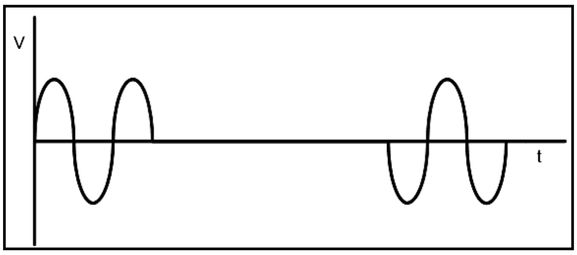

Fig. 3.6 Long Interruptions

4.2.5 Harmonic Distortion

Harmonic distortion is the change in the waveform of the supply voltage from the ideal sinusoidal waveform. It is caused by the interaction of distorting customer loads with the impedance of the supply network. Its major adverse effects are the heating of induction motors, transformers and capacitors and the overloading of neutrals. Power factor correction capacitors can amplify harmonics to unacceptable values in the presence of harmonic distortion. Harmonic distortion levels are described by the complete harmonic spectrum with magnitudes and phase angle of 6 each harmonic component [27].

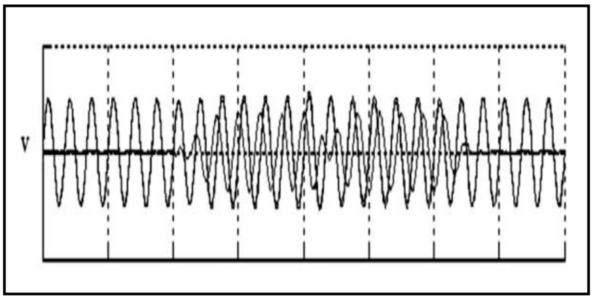

Fig. 3.6 Harmonic Distortion

Harmonic distortion levels can be described by calculating total harmonic distortion (THD) which measures the complete harmonic spectrum with magnitudes and phase angles of each individual harmonic component. THD is represented as the square-root of sum of the squares of each individual harmonic component.

V. CONCLUSION

The power quality problems such as voltage dips, swells and interruptions, consequences, and mitigation techniques of custom power electronic devices D-STATCOM. The design and applications of D-STATCOM for voltage sags, interruptions and swells, and comprehensive results are presented. The simulations carried out showed that the DSTATCOM provides relatively better voltage regulation capabilities. It was also observed that the capacity for power compensation and voltage regulation of DSTATCOM depends on the rating of the dc storage device. From Simulation model presented in the chapter it is clear shown that with a proposed control method the load unbalancing is been reduced considerably and also the THD that is the total harmonics distortion has been reduced considerably the waveform obtained with and without compensator.

REFERENCES

[1] N. G. Hingorani, “Introducing custom power,” IEEE spectrum, vol.32, no. 6, pp. 41-48, June 1995.

[2] L. Gyugyi, et al., “Principles and applications of Static, Thyristor-Controlled Shunt Compensators,” IEEE Trans. PAS, vol. PAS-97, no.5, Sept./ Oct. 1978.

[3] L. Gyugyi and E. R. Taylor, “Characteristics of Static Thyristor, Controlled Shunt Compensators for Power Transmission System Applications,” IEEE Trans. PAS, vol. PAS-99, no.5, pp. 1795- 1804, Sept/ Oct. 1980.

[4] K. R. Padiyar, FACTS Controllers in Power Transmission and Distribution, New Age International , New Delhi, 2007.

[5] N. G. Hingorani and L. Gyugi, Understanding FACTS, Concepts and Technology of Flexible AC Transmission Systems, Piscataway, NJ: IEEE Press (2000)

[6] Y. L. Tan, “Analysis of line compensation by shunt connected FACTs controllers: a comparison between SVC and STATCOM,” IEEE power Eng. Rev., 1999, vol. 19 (8), pp.57-58.

[7] P. Gonzalez and A. Cerrada, “Control System for a PWM-based STATCOM,” IEEE Trans. Power Delivery, vol. 15, pp. 1252-1257, Oct. 2000.

[8] B. Singh, R. Saha, A. Chandra and K. Al-Haddad, “Static Synchronous Compensators (STATCOM) : A review,” IET Power Electron., vol. 2, Iss.4, pp 297- 324, 2009.

[9] G. F. Reed, M. Takeda, F. Ojima, A. P. Sidell, R. E. Chervus and C. K. Nebecker, “Application of a 5MVA, 4.16kV D-STATCOM system for voltage flicker compensation at Seattle iron & metals,” IEEE PES SM, 2000, pp. 1605-1611.

[10] A. Ghosh and G. Ledwich, “Load Compensating DSTATCOM in Weak AC Systems,” IEEE Trans. on Power Delivery, vol. 18, no.4, Oct. 2003.

[11] S. Kincic and A. Chandra, “Distribution Level STATCOM (DSTATCOMs) for Load Voltage Support,” IEEE Proc. Power Engg. Conf. on Large Engg. Systems, pp 30-37, 2003.

[12] S. Bhattacharya, Po-Tai Cheng and D. M. Divan,“Hybrid Solution for Improving Passive filter performance in High Power Applications,” IEEE Trans. on Indus. App. vol. 33, no.3, May/ June 1997.

[13] H. Akagi, Y. Kanazawa, K. Fujita and A. Nabae, "Generalized theory of the instantaneous reactive power and its application," Electrical Engineering in Japan, Vol. 103, No.4, pp. 58-65, 198

[14] H. Akagi, Y. Kanazawa and A. Nabae. "Instantaneous reactive power compensators comprising switching devices without energy storage components:' IEEE Trans. Industry Applications, Vol. lA-20, No.3, pp. 625-630, 1984.

[15] H. Akagi, A. Nabae and S. Atoh, "Control strategy of active power filters using multiple voltage-source PWM converters," IEEE Trans. Industry Applications, Vol. IA-22, No.3, pp. 460-465, 1986.

[16] T. Furuhashi, S. Okuma, Y. Uchikawa, "A study on the Theory of Instantaneous Reactive Power," IEEE Trans. Industrial Electronics, Vol. 37, No. I, pp. 86-90, Feb. 1990.

[17] J. L. Willems, "A new interpretation of the Akagi-Nabae power components for nonsinusoidal three phase situations," IEEE Trans. on Instrumentation & Measurements, Vol. 41, No.4, pp. 523-527, 1992.